REMARKS

Upon entry of this amendment, which amends claims 46, 67, 97 and 98, claims 46-120 remain pending. Previously examined claims 46-52, 54-58, 60-65, 67-73, 84, 86-87, 89 and 92-95, 97-103, 105-109, 111-113, and 118 were rejected under 35 U.S.C. 103(a) as being unpatentable over USPN 5,689,128 to Hshieh *et al.* (herein "Hshieh '128") in view of USPN 5,719,422 to Burr *et al.* (herein "Burr"); claims 53, 59, and 74-83, 85, 88, 90-91, 104, 110, and 119-120 were rejected under 35 U.S.C. 103(a) as being unpatentable over Hshieh '128 and Burr further in view of USPN 6,204,533 to Williams *et al.* (herein "Williams"); and claims 66 and 114-117 were rejected under 35 U.S.C. 103(a) as being unpatentable over Hshieh '128 and Burr.

Applicants respectfully request reconsideration of the claims in view of the above amendments and the remarks below.

- The rejection

The rejection maintains that Hshieh '128 discloses all of the elements of independent claims 46, 67 and 97, except that Hshieh '128 "does not expressly describe [] an abrupt junction." The rejection continues (at page 3):

> It should be noted that even though the cited reference does not mention the function of the heavily doped region as abrupt junction. But the structure of the deeper doped well and a second well of an opposite dopant may create an abrupt junction as claimed since the concentration of these regions is typically different as described in the current application. In the current specification, the Applicants further admit that this abrupt

This passage indicates that the confusion surrounding the polarities of the two regions at the interface of which the claimed abrupt junction is formed persists. Applicants respectfully submit that regions 14 and 18 in Fig. 3 of Hshieh '128, alleged by the rejection to correspond to the

claimed "doped well" and "doped heavy body" respectively, have the *same* polarity dopants and not "opposite dopant" as stated by the rejection. The claims have been amended to further underscore this aspect of the invention.

Further, as previously stated, merely because two adjacent regions (whether of opposite polarity or same polarity) are characterized as having different dopant concentrations, it does not follow that the junction at their interface is "abrupt." The distinction here is between a "linearly graded" junction (as in a long gradual ramp between two points having different elevations) versus an "abrupt" junction (a shorter steep ramp between the two points). That is, the nature of the "junction" or the interface between the two regions is determined by the distance over which the change in concentration occurs not the nominal dopant concentrations of each region. Accordingly, the concentration profile of an abrupt junction where the change in concentration between two same-polarity regions occurs over a relatively shorter distance will appear as a kink or dog leg shaped bend shown in FIG. 5 of the present application. An annotated FIG. 5 of the present application is reproduced below with the relevant regions and the location of the abrupt junction highlighted:

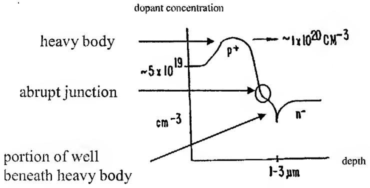

FIG. 5.

Without an abrupt junction the downward slope of the P+ heavy body curve would show no such kink and would instead appear as a smooth curve similar to the P- curve (P well concentration) shown in FIG. 5A of the present application reproduced below.

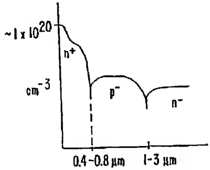

FIG. 5A.

Nowhere in Shieh '128 is there any disclosure or suggestion of forming regions such that at their interface an abrupt junction is formed. The rejection contends:

> application. In the current specification, the Applicants further admit that this abrupt junction can be formed by different methods, for example, diffusion, implantation, etc. Hshieh also teaches that the dopants are introduced in the substrate by a method of implanting the dopant. In order to justify the analisis as mentioned, Burr is incorporated

Semiconductor junctions are formed by various known methods one of which is ion implantation. The fact that both the present invention and Hshieh '128 discuss forming doped regions by ion implantation, by itself, does not render the junctions at the interface of these doped regions abrupt. A first doped region formed by ion implantation into a second region can either result in a junction (or interface) that is abrupt or one that is linearly graded. The nature of the interface will depend on various factors including dosage and energy of implantation, background doping of the second region, any subsequent heat cycles, among several other factors. The rejection continues:

> implanting the dopant. In order to justify the analisis as mentioned, Burr is incorporated herein to further explain how a such junction can be formed. For example, Burr, in fig. 1, discloses an analogous device, a low threshold voltage high performance junction transistor transistor, and the structure includes regions of the same dopant, P-type, 46 and 34. These regions are formed by dopant implantation method and also have a typical concentrations different from each other; therefore, they form a abrupt junction therebetween in order to form a high performance device because this junction provides a low threshold voltage, and provides the growth of the depletion regions is immediately slowed. See also, Burr's col. 7, lines 25-30, and 55-55.

Based on the above, the rejection concludes that it would have been obvious "to recognize the structure that could create such junction as taught by Burr in Hshieh's device in order to take the advantage as mentioned." Applicants respectfully disagree.

First, similar to Hshieh '128, nowhere in Burr could there be found any mention of the term "abrupt." Second, even if Burr did disclose or suggest an abrupt junction, Applicants respectfully submit that one of ordinary skill in the art would not combine Burr with Hshieh '128 for several reasons. Burr teaches a planar MOSFET where the gate (42) is formed on the top surface of the substrate (32) as shown in all figures of Burr including FIG. 1 reproduced below:

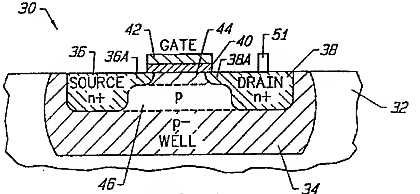

FIG. 1

Burr's is a fundamentally different structure than a trench transistor wherein the transistor gate is formed inside a trench. As described at, for example, the paragraph bridging pages 6 and 7 of the instant application, the claimed structure, including the abrupt junction, is intended to protect the gate oxide inside the trench, especially at trench corners that typically attract the electric field. This is accomplished, in part, by optimally locating the abrupt junction which attracts the peak electric field away from trench corners. In the Burr transistor, by contrast, there are no trench corners that would attract the peak electric field. Instead Burr teaches the use of a "buried electrode region 46" to obtain a low Vt transistor without increasing the likelihood of punch through. [See, e.g., Burr, col. 7, lines 30-47.]

Accordingly, the Hshieh '128 patentee which was concerned with addressing destructive breakdown at the bottom of the trenched gate structure while minimizing chip surface area [col. 1, lines 25-50], would not look to references such as Burr that disclose planar (as opposed to trench) gate devices. Moreover, even if the Hshieh '128 patentee did consider Burr's teachings, the rejection's purported motivation to combine would not apply since Hshieh '128 is not concerned with reducing threshold voltage. No combination of these references thus teaches or suggests an abrupt junction to move the peak electric field away from the trench in combination with the other elements of the transistor as claimed.

All independent claims have been amended to recite that the "gate structure is formed inside the trench" in order to expressly differentiate the trench gate structure of the claimed transistor from planar gate transistors of the type disclosed in Burr. Claims 46 and 67 have been further amended to specify that the "peak electric field occurs near the area of the interface" between the heavy body and the well (i.e., near the abrupt junction). And claim 97 has been amended to recite "the depth of the doped heavy body region relative to the depth of the doped well is selected so that a peak electric field, when voltage is applied to the transistor, is spaced away from the trench." Again, the cited references taken together fail to teach or suggest these features in combination with the other elements as claimed in independent claims 46, 67 and 97.

Accordingly, independent claims 46, 67 and 97 are patentably distinguished over the cited references.

All claims depending from claims 46, 67 and 97 are similarly patentably distinguished over the cited references for at least the reasons stated above. The dependent claims, however, recite additional features that further distinguish over the cited references. For example, with respect to claims 52 and 103, the rejection states that Hshieh '128 in Fig. 3 discloses forming the heavy body (alleged as region 18 in Hshieh '128) by implanting the dopants at an approximate location of the abrupt junction (52) or the junction with the doped well (103). As previously explained, region 18 in Hshieh '128 is a "doped body contact region" whose function is "to promoate contact between the body region 14 and the overlying source-body metallization layer 30." [Hshieh '128, col. 3, lines 38-40, underline added.] That is, Hshieh '128 does not teach or suggest an "abrupt junction" as in claim 52, nor a junction that impacts the location of the peak electric field as in claim 103. Nothing could be found in Hshieh '128 teaching that the "body contact region 18" is implanted at any particular depth, let alone the approximate location of the abrupt junction or the junction with the well.

Other examples of dependent claims that recite additional distinguishing features include all of the various claims that are directed at the relative depths of the heavy body region and the doped well including claims 65-66, 95-96 and 116-117. Claims, 65, 95 and 116, for example, define the "distance between a bottom of the doped heavy body to the doped well junction" as ranging "from approximately $0.5\mu m$ to $1.5\mu m$." The rejection states:

> In regard to claims 65, 95, and 116, wherein a distance between a bottom of the doped heavy body to the doped well junction ranges from approximately 0.5 to 1.5 microns. Figure 3 depicts this range since region 14 is 2.5 microns and heavily doped region 18 extends at least half way of the region 34. See col.3, lines 15-19 and fig. 3.

Applicants respectfully submit that the rejection's analysis is incorrect because the dimensions mentioned by the rejection relate to the Fig. 1 embodiment of Hshieh '128 and not Fig. 3. There is a very significant difference between the embodiment shown in Fig. 1 in that the P doped body region 14/16 is even deeper than the trench as shown in Fig. 1 of Hshieh '128 reproduced below:

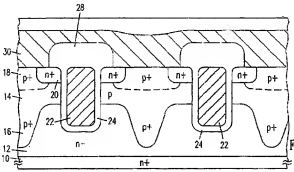

FIG. 1

The embodiment shown in Fig. 1 of Hshieh '128 is the type of prior art transistor structure that the present invention improves upon by eliminating the deep P+ region to allow for more compact cell design. In fact, since Hshieh '128 attempts to address the breakdown problem by other means such as the provision of "a second (upper) epitaxial layer (drift region) 34" in the other two embodiments shown in Figs. 2 and 3, Hshieh '128 neither attaches any significance to nor specifies any dimensions or spatial relationship between the bottom of the heavy body and the doped well region. By contrast, for some embodiments of the present invention, this spatial relationship is one of the key structural features that enables the improvement in breakdown performance. See, e.g., the sentence bridging pages 2 and 3, as well as lines 17-22 of page 6 of the instant application. With respect to claims 66, 96 and 117, the rejection states:

> At the time of the invention was made, it would have been obvious to a person of ordinary skill in the art to modify the thickness of this region because applicant has not disclosed that this thickness provides an advantage, is used for a particular purpose, or solves a stated problem. One of ordinary skill in the art, furthermore, would have expected applicant's invention to perform equally well with either shape because they perform the same function of promoting electrical contacts between regions, in this case, regions 14 and layer 30.

Again, the rejection is based on a misunderstanding of this aspect of the present invention. The claimed thickness or spatial relationship between the bottom of the heavy body and the doped well junction is not for the purpose of "promoting electrical contacts between regions" as stated by the rejection. Instead, as clearly stated in at least a couple of instances in the present application, including at the sentence bridging pages 2 and 3, as well as lines 17-22 of page 6 of the instant application, the claimed thickness or spatial relationship helps move peak electric field away from trench corners thereby providing a significant advantage. Neither of the cited references alone or in combination teaches or suggest these claimed features in combination with the other elements of the claims.

In summary, Applicants would like to stress that the structure and properties of the abrupt junction were well understood in the prior art. Applicants further submit that the problems associated with the design trade offs in trench power transistors including, for example, improving breakdown characteristics at the cost of on resistance were also well known in the prior art for many years as illustrated by Hshieh '128 and multiple other prior art references considered throughout the prosecution of this application and its parent applications. Yet, time and again, approaches other than the presently claimed invention were offered by the industry. These include the three different embodiments in Hshieh '128 as well as several other approaches discussed previously. If it were obvious that the provision of a "heavy body" region inside the well can appreciably impact the location of the peak electric field in a trench transistor as claimed, publications describing it and products adopting it would have been found in public domain years earlier. It was not until the inventors of the present application conceived of the claimed combination, conducted further research and countless computer simulations and successfully manufactured trench power transistors based on the claimed technology that the claimed invention proved its efficacy and advantages. Applicants respectfully submit that no combination of the prior art teaches or suggests the claimed combinations.

CONCLUSION

In view of the foregoing, Applicants believe all claims now pending in this Application are in condition for allowance. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

If the Examiner believes a telephone conference would expedite prosecution of this application, please telephone the undersigned at 415-576-0200.

Respectfully submitted,

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